

On-Board Recording for Commercial Motor Vehicles and Drivers: Microscopic and Macroscopic Approaches

*Neill L. Thomas and Deborah M. Freund
Office of Motor Carrier and Highway Safety
Federal Highway Administration
400 7th Street, SW, Washington, DC 20590-0001*

KEYWORDS

Highway, operational, performance, planning.

INTRODUCTION

Approximately 2.3 million drivers operate commercial motor vehicles (CMVs) in interstate commerce. Crashes involving these vehicles are important safety concerns of the Federal Highway Administration (FHWA) for several reasons (FHWA, 1999):

- On average, CMVs travel 5-10 times the annual miles of passenger cars. Although the crash rate of CMVs has held steady for several years, the number of crashes has risen because the number of vehicles and distance traveled both are increasing.
- Heavy trucks make up 3% of the registered vehicle population in the United states, account for 7% of all vehicle miles traveled, but represent 9% of motor vehicles involved in fatal crashes.
- CMV-related fatal crashes and injuries cost the U.S. economy \$15 billion annually.
- Non-CMV vehicles and their drivers bear most of costs of CMV-related crashes: 85% of fatalities, 75% of injuries, 67% of economic losses.

Hours-of-service of CMV drivers are covered under the Federal Motor Carrier Safety Regulations (FMCSRs), at Title 49, Part 395, of the Code of Federal Regulations. The regulations prohibit a driver from driving more than 10 hours following a minimum of 8 consecutive hours off-duty, or driving after 15 hours on-duty [including any driving time] following a minimum of 8 consecutive hours off-duty. They require a driver to be given at least 8 consecutive hours off duty between driving and on-duty periods. Drivers are also prohibited from operating a CMV after accumulating 60 hours on-duty in any 7 consecutive day period (if the motor carrier does not operate its vehicles every day of the week), or 70 hours in any 8 consecutive days (if the motor carrier operates CMVs every day of the week). The requirement for CMV drivers to record their hours-of-service, and for motor carriers to maintain those records is included in regulations written in 1939 and still in effect. The record of duty status (RODS), commonly known as a driver's log, must be completed by all CMV drivers operating in interstate commerce. Details of the requirement are contained in 49 CFR 395.8.

Because compliance with hours-of-service regulations (i.e., not exceeding maximum driving and duty time limits, and being afforded at least the minimum off-duty time for purposes of obtaining rest) has a strong influence on the ability of a driver to perform safely, the recording of duty status and time becomes an essential regulatory issue.

We believe there are merits to both macroscopic (vehicle and operationally-oriented) and microscopic (driver self-monitoring) approaches for planning and monitoring duty and non-duty times to enhance safe

and productive CMV transportation. Two FHWA projects -- a research study and an operational test -- are exploring the feasibility of these different, yet complementary, approaches.

RECORDING HOURS OF SERVICE

The FHWA estimates that 1.6 million drivers are required to prepare RODS. The amount of time required to fill out a RODS varies with the number of stops and changes in a driver's status (from on-duty-driving to on-duty-not-driving, for example), but the FHWA estimates approximately two minutes per driver per workday. The agency estimates that these drivers and their motor carriers incur a time burden of 14.3 million hours annually. The annual direct costs of drivers' RODS, not including wage and hour costs, are estimated to be \$22.9 million. This is the third-highest paperwork burden of all FHWA regulations, and is among the 10 highest in the DOT.

An option of using a simpler record is available to drivers who operate within a 100 air-mile radius of their normal work reporting location, and who are released from work within 12 consecutive hours of the time they report for work. These drivers may use time cards (required by statute and the regulations administered by the Wage and Hour Division of the U.S. Department of Labor) instead. The FHWA estimates that just under 700,000 drivers fall into this category. **WHY SHOULD MOTOR CARRIERS ADOPT TECHNOLOGY?**

Technological tools must justify their worth to their potential users by fulfilling promises of cost savings and improved operational efficiency. Motor carrier transportation has high capital and operational costs and narrow profit margins -- saving fractions of a cent per mile can make the difference between a profitable and a money-losing operation.

Potential savings can be derived through improved communications and operational oversight. This enables motor carriers and drivers to plan trips more efficiently to minimize deadhead miles and fuel consumption, as well as ensuring that drivers have sufficient duty hours available to complete a trip in compliance with the regulations. Automated entry and review of operational information can also generate significant time and personnel savings for both drivers and the back-office part of an operation, as well as providing trend information. Much of the impetus for motor carriers' first petitions to the FHWA to allow automatic on-board recording systems came from a desire to automate the entry and review of RODS data (U.S. Department of Transportation, 1988). The increasing availability and declining costs of real-time satellite communications are driving the trend towards real-time operational monitoring, which we will describe in this paper.

Savings can also be derived from avoidance of adverse occurrences, such as crashes and non-crash incidents. A crash is both a human tragedy and a very costly event. Assuming a 2% profit margin, a motor carrier needs to generate an additional \$250,000 of revenue to cover the losses from a \$5,000 crash. The losses could include repair costs, lost revenue while vehicles are being repaired, insurance claims, cargo damage, increased insurance premiums and customer relationships (FHWA, 1993).

The human-factors research programs of the FHWA and the National Highway Traffic Safety Administration have placed, and continue to place, a strong emphasis on crash-avoidance warning systems. These have included lane-drift-warning devices, vehicle proximity sensors, and continuous in-vehicle alertness monitoring based on physiological measurement. In this last area, an eyelid closure measure called "PERCLOS" has received considerable attention as a benchmark measure of operator alertness when compared with driving performance related measures. All of these warning systems have considerable potential value to alert a driver of imminent threats. Another class of driver-oriented

devices has the potential to be able to predict drivers' performance levels based on the timing, length, and quality of prior sleep and activity periods. One such device is the Actigraph, developed by the Walter Reed Army Institute of Research, to be discussed later in this paper.

Vehicle-Based Operational Approaches

In 1986, the FHWA granted a motor carrier's request to use an automatic interactive on-board recorder to record drivers' hour-of-service. On September 30, 1988, the FHWA revised its hours-of-service regulations to allow motor carriers, at their option, to use certain automatic on-board recording devices to record their drivers' records of duty status in lieu of using the handwritten records of duty status required under 49 CFR 395.8. This provision is codified at 49 CFR 395.15.

The FHWA has noted that many motor carriers that employed that technology found that their compliance with the hours-of-service regulations improved. Emerging technologies are causing the narrowly crafted on-board recorder provision to become outdated (FHWA, 1998). Conventional on-board recorders do not provide real-time information to the motor carrier -- they are downloaded at intervals ranging from daily to weekly. New satellite communications technologies, such as those based on global positioning systems (GPS) technology, can provide this real-time link. These technologies can provide a superior, proactive, "real time" approach to monitoring and controlling drivers' hours. The FHWA posited that the GPS technology and many of the complementary safety management computer systems currently being used by the motor carrier industry provide at least the same degree of monitoring accuracy as the "automatic on-board recorders" allowed by the FMCSRs.

GPS TECHNOLOGIES PILOT DEMONSTRATION PROJECT

On April 6, 1998 the FHWA announced a voluntary program under which a motor carrier using global positioning systems (GPS) technology and related safety management computer systems could enter into an agreement with the FHWA to use the systems in a pilot demonstration project to record and monitor drivers' hours of service in lieu of complying with the handwritten driver log requirements of 49 CFR 395.8 or the conventional on-board recording requirements of 49 CFR 395.15. Consistent with the President's initiatives in reinventing government and regulatory reform, the agency has designed the project to demonstrate whether the motor carrier industry can use the technology to improve compliance with the hours-of-service requirements in a manner which promotes safety and operational efficiency while reducing paperwork requirements (FHWA, 1998).

The FHWA's starting point for defining the parameters of an automatic on-board recording device that would meet the requirements of 49 CFR 395.15 is defined at 49 CFR 395.2: "an electric, electronic, electromechanical, or mechanical device capable of recording driver's duty status information accurately and automatically ... The device must be integrally synchronized with specific operations of the commercial motor vehicle in which it is installed. At a minimum, the device must record engine use, road speed, miles driven, the date, and time of day." Conventional mechanical tachographs are highly subject to tampering and do not comply with the requirement.

There are limited provisions of § 395.15 that are not entirely adaptable to GPS technology and related computer systems. Table 1 sets out those provisions and then describes what the GPS technology and related computer systems have available to satisfy, or go beyond, what is required by § 395.15.

49 CFR 395.15	GPS TECHNOLOGY
§ 395.15(a)(1) permits use of "Automatic on-board recording device" (OBR) as defined at 49 CFR 395.2:	Records driver's duty status accurately and automatically ... not "integrally synchronized" with specific CMV

49 CFR 395.15	GPS TECHNOLOGY
capable of recording driver's duty status accurately and automatically ... must be integrally synchronized with specific CMV functions ... must record engine use, road speed, miles driven (axle revolutions), date and time of day (internal clock).	functions ... Computes distance traveled by vehicle position readings (latitude/longitude) provided by satellite ... Road speed estimated by time elapsed between vehicle position readings.
§ 395.15(b)(3) Support systems: must provide information about on-board sensor failures and identify edited data.	Support systems provide information about on-board system failures and identify edited data.
§ 395.15(f) Reconstruction of records of duty status: Drivers must note any failure of automatic OBRs and reconstruct records of duty status (RODS) for current day and past 7 days ... must prepare handwritten RODS until device is operational.	If communications to CMV fail, vehicle position and sensor readings continue to be recorded by satellite and sent to terminal ... retransmitted to CMV after communications are restored ... Drivers can immediately request, by telephone, the previous 7 days RODS be sent via facsimile to roadside location ... unnecessary to reconstruct RODS.
§ 395.15(h)(1) Submission of RODS: Driver must submit, electronically or by mail, to motor carrier, each RODS within 13 days following completion of each RODS.	Provides motor carrier automatically with access to all driver and vehicle records on a continual, "real-time," basis.
§ 395.15(h)(2): Driver must review and verify all entries are accurate before submission to motor carrier.	Motor carrier furnishes driver with duty status summary ... duty status entries available to driver for review and verification daily.
§ 395.15(h)(3): Submission of RODS certifies all entries are true and correct.	Driver's verification message certifies all entries are true and correct.
§ 395.15(i)(1): Motor carrier must obtain manufacturer's certificate that the design of OBR meets requirements.	The FHWA provides written approval.
§ 395.15(i)(2): Duty status may be updated only when CMV is at rest, except when registering time crossing State boundary.	Company policy prohibits any entry while CMV is in motion ... records violations automatically ... takes remedial action.
§ 395.15(i)(3): OBR and support systems must be, to the maximum extent practicable, tamper proof.	Provides time, location, and sensor signals by satellite service. System provides audit trails of all keyboard interactions.
§ 395.15(i)(4): OBR must warn driver visually and/or audibly the device has ceased to function.	Provides audible and/or visible warnings to CMV driver and motor carrier.
§ 395.15(i)(7): OBR and support systems must identify sensor failures and edited data.	Provides audit trails of all sensor failures and edited data.
§ 395.15(i)(8): OBR must be maintained and recalibrated in accordance with the manufacturer's specifications.	Performs maintenance in accordance with manufacturer's specifications ... Renders calibration unnecessary.

Table 1

In June, 1998, Werner Enterprises, Inc. of Omaha, NE became the first motor carrier to enter into such an agreement with the FHWA. The next month, over 5,000 Werner drivers were operating without the paperwork burden associated with paper log books. Although Werner is the only motor carrier that has

been approved by the FHWA to participate thus far, a number of other motor carriers have expressed interest. The FHWA is currently reviewing their programs and procedures and has extended its deadline for applying to participate until June 30, 1999.

The FHWA plans to evaluate the success of the demonstration project according to four criteria: Level of compliance with the hours-of-service regulations, accident involvement, reduction in paperwork burden, and improvements in operational efficiency (i.e., costs associated with preparing, reviewing, and retaining hours-of-service data). The FHWA believes this project will demonstrate that the motor carrier industry can use GPS technology to improve compliance with the hours-of-service regulations in a manner which promotes safety and operational efficiency while reducing paperwork requirements.

LIMITATIONS OF ON-BOARD RECORDERS

There are significant outstanding issues relating to the practicality of state-of-the-practice on-board recorders (OBR). Currently available devices cannot record the activity of the driver while the driver is not in a "driving" status. They cannot discriminate among any of the myriad activities that constitute "on duty, not driving," and science tells us that the physical and mental exertion associated with these tasks can differ significantly. Current devices also cannot discriminate between on-duty-not-driving and off-duty activities.

There are also substantial concerns regarding the costs and benefits of current on-board recorders. The FHWA engaged the University of Michigan Transportation Research Institute (UMTRI) to study the applicability of on-board recorders to motor carrier operations. Motor carrier fleet response rates for this study were very low, possibly because of early adverse industry commentary on the study. The study, completed in late 1998, found that (1) large fleets were far more likely to use on-board recorders (however 90 percent of motor carriers operate fewer than 9 trucks or buses) and (2) the overwhelming fleet view is that mandatory OBR use would require extremely high expenditures for minimal operational benefits. The study did not address relationships between on-board recorder use and hours-of-service regulations compliance, nor between hours-of-service compliance and overall safety posture.

DRIVER-ORIENTED APPROACHES

Regulations mandating specific equipment have had the effect of limiting and stifling the development of new devices that would go beyond the strict terms of the regulation. Here, the regulatory "floor" becomes the de-facto "standard." We believe that, ultimately, performance-based approaches geared toward driver proficiency -- especially in a predictive mode -- may play a significant role towards ensuring driver alertness and performance.

WORK AND REST SCHEDULES AND DRIVER PERFORMANCE

Several major transportation and industrial disasters -- *Challenger*, Bhopal, Three Mile Island, and Exxon *Valdez* -- had a common set of defining elements: combined time-of-day and sleep-loss effects and severe performance decrements on the part of operators and crews. In their consensus report for the Association of Professional Sleep Societies (Mitler, et. al., 1988) several prominent sleep researchers provide an overview of contemporary research on relationships between the biological clock and human sleepiness and sleep vulnerability, as well as studies of temporal trends of mortality, single-vehicle highway accidents (such as run-off-road), and major engineering and industrial disasters. The authors recommended, among other things, that research be performed to assess the effects of less-than-adequate sleep, even as little as a loss of 1-2 hours, on the tendency for operators to commit errors during the time periods of increased vulnerability to sleepiness.

Most studies of “fatigue” have focused upon the ability to perform tasks requiring motor skills, or upon the effects of total sleep deprivation on physical and mental performance. However, cognitive performance deteriorates faster than motor skills and is seen earlier in partial sleep deprivation. Controlled laboratory studies and assessments of “friendly fire” incidents in the military have demonstrated that an individual may continue to be capable of performing a specific task, but not have sufficient awareness of the general situation, nor the ability, when called for, to move away from a highly conditioned automatic response (Belenky, 1995)

As described earlier, the hours-of-service (HOS) regulations include minimum off-duty times between driving and duty periods, as well as cumulative limits in 7- or 8-day duty cycles. Many motor carriers and drivers have expressed a desire for the duty cycle to be “reset” after a certain amount of off-duty time. This could have the outcome of increasing the 7- or 8-day duty and driving totals significantly. However, a literature review (Tepas, 1992) found no sources of data on rest and recovery cycles, nor on partial sleep deprivation and prediction of subsequent performance. An ongoing study being conducted by the Walter Reed Army Institute of Research helps fill these gaps.

The study is (1) gathering field data on representative wake-sleep cycles of CMV drivers operating in uncontrolled, naturalistic settings; (2) gathering data in a laboratory setting to determine quantitative relationships between sleep amount (“sleep dose”) and driving task performance, physiological state, and subjective responses; and (3) using the laboratory and field data to validate and extend a numerical model (Sleep Performance Prediction Model, or SPM) to predict performance based on prior wake-sleep cycles, sleep quality and quantity, and circadian state for a next-generation wrist-worn activity monitor (Actigraph).

In the first phase of this study, data were collected from 25 local and 25 long-distance CMV drivers who wore Actigraphs for 20 consecutive days while engaged in their normal duty and off-duty activities. The Actigraph data indicated that the short-haul drivers averaged 7.7 hours of sleep/24 hours (with 7.5 hours taken while off duty and 0.2 hours taken as naps). The long-haul drivers averaged 7.3 hours of sleep/24 hours (4.3 hours taken off duty and 3.0 hours taken as naps).

In the second phase, 66 drivers participated in a 14-day laboratory study. The drivers were allowed 8 hours in bed each night for the first 3 “baseline” days. On the third day, they were randomly assigned to one of 4 sleep conditions: 9, 7, 5, or 3 hours in bed each night over the next 7 days. The drivers were again allowed 8 hours nightly time in bed during the final 3 “recovery” days of the study. The drivers were tested for cognitive performance (e.g., serial addition/ subtraction task, PC-based driving simulator, and psychomotor vigilance task (PVT)) and alertness (e.g., multiple sleep latency test and Stanford sleepiness scale) periodically throughout each day. Sleep was monitored using standard polysomnographic measures (EEG, EOG, and EMG). The drivers also wore Actigraphs for the entire period.

Initial study results indicate that the 9-hours-in-bed condition resulted in sustained performance and alertness over the experimental period; this may be regarded as the “optimal” time in bed in this study. The 7-hours-in-bed condition resulted in slight but progressive and statistically-significant declines in PVT performance over successive days. However, on other performance measures there was some overlap between the 9- and 7-hour groups, thus indicating no significant decline in performance associated with 7 versus 9 hours in bed for these measures. The 5-hours-in-bed condition was associated with major declines in performance and alertness on all measures. And, not surprisingly, the 3-hours-in-bed condition had the steepest progressive declines on all measures. In short, the results overall have shown systematic, orderly declines in performance/alertness across the 4 sleep conditions.

The SPM model is undergoing testing, validation, and refinement, incorporating results of the laboratory

and field tests. Walter Reed is working collaboratively with researchers at Indiana University-Purdue who will address this complex modeling challenge with new computational intelligence techniques.

The new SPM model will be applied to these data to model/predict the effects of these real-world schedules on metrics based on cognitive performance (serial addition/subtraction), driving (performance on simulator), and vigilance and reaction time (PVT). Since another study has validated the eye closure measure PERCLOS in terms of the PVT, the new SPM model should also be able to predict future PERCLOS scores based on sleep/wake history. The new SPM will be integrated into the Actigraph with an improved sleep-scoring algorithm, also under development, for future field-testing and validation.

The study will provide crucial information concerning potential use of personal monitors to prevent fatigue and loss-of-alertness through application of a performance-based assessment. Drivers and motor carriers could gain benefits unavailable under the current prescriptive regulatory system. Drivers could be able to better gauge their present and projected alertness and performance levels, and be able to alter their activity (increase main sleep or take naps) to improve alertness and projected performance. Motor carrier personnel could also be better informed of the drivers' alertness and performance status to optimize both productivity and safety. The driver-oriented and the operationally-oriented approaches could thus converge in a comprehensive safety-proactive paradigm.

CAVEATS AND CONCERNS WITH OPERATIONAL MONITORING

The operational tests of continuous monitoring systems and on-board monitors include several classes of devices for monitoring safe operating performance of the driver and the CMV. Driver-oriented monitoring devices envisioned include devices to measure eye and eyelid movement. These have been shown in laboratory settings to be closely related to driver drowsiness. The Actigraph would allow a driver to self-monitor his or her alertness at a given point in time, and to predict periods of high and low alertness up to several hours in the future. Vehicle-oriented devices might include sensors to measure steering patterns and how well the CMV is tracking in the driving lane.

We expect that technologies for monitoring drivers' alertness and performance would be used primarily by the drivers themselves as tools to help them plan their own wake and sleep schedules, and to adjust their activities (including taking naps and sleep breaks, as necessary) if their alertness level is not sufficient for them to continue driving safely. Motor carriers might elect to use them as part of their proactive safety assurance programs, and require drivers to use them as a condition of employment. We do not foresee active monitoring by the government of drivers or their vehicles via any of these technologies. We believe that the federal government might be more inclined to review detailed data on an individual driver's activity only if there were a compelling reason (such as a crash where we believed driver drowsiness was a contributing factor, and the motor carrier did not document the driver's activities via a record of duty status or by other reliable means). Whether the government would require, at some future time, the use of alertness or performance monitoring devices remains an issue under consideration as we expand our knowledge of the capabilities and costs of various systems.

The FHWA is studying drivers' concerns about the use of information from on-board intelligent transportation systems (ITS) technologies. A recent research study (Penn + Schoen, 1995) asked nearly 1600 drivers for their opinions on six classes of existing and evolving ITS/commercial vehicle operations (CVO) services: fleet management, electronic clearance, administrative processes, roadside safety inspection, hazardous materials incidence response, and on-board safety monitoring. The findings indicated that "... on the whole, commercial vehicle drivers are receptive to and supportive of the use of the CVO service on the road and in their vehicles. Technologies which received the most support were those that 'would make my work easier,' are 'useful for me,' and 'will work [in my vehicle]/I would rely on it.'" The report went on:

“However, there was some concern that certain of the technologies would be an invasion of driver privacy by either the government or the driver’s company, and also a concern that the systems would rely too much on computers and diminish the role of human judgment. Drivers were wary of services that promised too much and would leave them dependent on unproven, inexperienced technology. They wanted systems that would be reliable, workable, and useful on a consistent basis, and would not pose a threat to themselves, their vehicles, their privacy, or their livelihood.”

Furthermore, the report indicated that

“... drivers tended to evaluate the CVO services from the perspective of their personal experience, rather than focusing on the bigger picture of the industry as a whole. For example, independent owner-operators, who have historically been more skeptical of technology and wary of intrusion by the government or companies, reacted more negatively toward the technologies than did other drivers ...”

In general, drivers were less favorably inclined towards the onboard safety monitoring service than the other CVO services. “While a majority of respondents were able to recognize the potential safety benefits of this service, the idea that technology was too invasive and too reliant on computers made some respondents unwilling to accept this service.”

Another study assessed the potential for automated hours-of-service recording via use of smart-card systems. This study responded to Congressional direction to the Federal Highway Administration contained in the agency’s 1995 appropriations bill to: “... test the feasibility of a smart [card] system to enhance the security and utility of the commercial driver’s license and enforcement of hours-of-service regulations.”

Smart cards, for the purposes of this study, were defined as credit card-sized plastic cards with an embedded integrated circuit chip containing a central processing unit, random access memory, and non-volatile data storage. The research contractor assessed technological, economic, and institutional factors requiring consideration if smart-card applications were to be implemented.

The researchers determined that three smart-card applications were feasible: driver’s license, vehicle card (for operating credentials and maintenance purposes), and electronic toll collection. Two others were determined not to be feasible: international border crossing (because data transfer via telecommunications already is in place under the U.S. Customs Service) and driver record of duty status. The contractor noted three obstacles to implementing the latter:

“Current federal regulations do not require motor carriers to automate the Driver Record of Duty Status. Any proposed regulation specifying the use of smart cards would almost certainly encounter fierce opposition ... All ITS programs are voluntary, and the federal government would jeopardize carrier participation in other ITS activities if it tried to mandate the use of smart cards.”

The Fair Information Principles for ITS/CVO adopted in June, 1998 by ITS America include a “secondary use” provision as follows: “Data collected by the private sector for its own purposes through a voluntary investment in technology over and above those data required by law should not be used for enforcement purposes without the carrier’s consent.”

Finally, Dinges (Dinges, 1997) and others have pointed out major concerns in identifying, developing, and

setting standards in the quest to develop technological approaches to managing transportation operator fatigue and vigilance. The approaches must be assessed in terms of sound science and engineering criteria. They must be practical and implementable. Last, but definitely not least, they must be defensible from legal and public policy perspectives. Dinges closes with this statement:

“Technologies may eventually prevent or limit certain catastrophic outcomes due to fatigued performance, but technologies are not substitutes for setting societal standards for the functional capability of an operator. On the other hand, technologies can help establish and maintain adherence to that standard if they are developed and used in a valid and responsible manner.”

We believe the GPS technologies pilot project will demonstrate that the motor carrier industry can use this technology to improve compliance with the hours-of-service regulations in a manner which promotes safety and operational efficiency while reducing paperwork requirements.

We believe drivers are likely to use personal alertness and performance monitors such as the Actigraph to help them plan their own wake and sleep schedules, and to adjust their activities (including taking naps and sleep breaks, if necessary) if their alertness level is not sufficient for them to continue driving safely.

Motor carriers might also elect to use them as part of their proactive safety assurance programs, or require drivers to use them as a condition of employment.

REFERENCES

3-G International *Smart Cards in Commercial Vehicle Operations*. Report No. FHWA-MC-97-022 1996.

Belenky, G. “Sleep, Sleep Deprivation, and Continuous Operations.” *Army RD&A*, May-June 1995.

Campbell, K., Lang., Smith, M. (1998) *Electronic Recorder Study*. Federal Highway Administration. (Report No. UMTRI-97-34 available from the University of Michigan Transportation Research Institute).

Dinges, David F. “The Promise and Challenges of Technologies for Monitoring Operator Vigilance.” Proceedings, *Managing Fatigue in Transportation*. American Trucking Associations Foundation, Alexandria, Virginia, April, 1997.

Federal Highway Administration, *Accident Countermeasures Course*. October 1, 1993 edition.

Federal Highway Administration, *1997 Large Truck Crash Overview*. Publication FHWA-MC-99- 021. Federal Highway Administration, “Modeling of Driver Performance under Various Work-Rest Schedules” in *Summary of Driver Fatigue Programs* (December, 1998). (Available from Federal Highway Administration, Office of Motor Carrier Research and Standards).

ITS America Staff. “CVO Policy Subcommittee Approves Privacy Principles.” *CVO Update*, Spring, 1998.

Johnson, D., Thorne, D., Rowland, L., Balkin, T., Sing, H. et. al. (1997) “The Effects of Partial Sleep Deprivation on Psychomotor Vigilance.” *Sleep Research*, 26, 627 (Abstract).

Mitler, M.M., Carskadon, M.A., Czeisler, C.A., Dement, W.C., Dinges, D.F., Graeber, R.C. "Catastrophes, Sleep, and Public Policy: Consensus Report." *Sleep* 11(1):100-109, Raven Press, Ltd., New York. 1988.

Department of Transportation, Office of the Secretary of Transportation, Reports, Forms, and Recordkeeping Requirements; Agency Information Collection Activity Under OMB Review: Federal Highway Administration renewal of OMB Information Collection 2125-0016; Supporting Statement. August 6, 1998 (63 FR 42091).

Penn + Schoen Associates, Inc. *Critical Issues Relating to Acceptance of CVO Services by Interstate Truck and Bus Drivers*. Federal Highway Administration Contract DTFH61-94-C-00182. 1995.

Tepas, D. "Literature Review and Critique of Past Research on the Rest and Recovery Cycles of Commercial Motor Vehicle Drivers." Contract DTFH61-91-P-01179, Final draft report. September, 1992. (Available from Federal Highway Administration, Office of Motor Carrier Research and Standards).

Thorne, D., Thomas, M., Sing, H., Balkin, T., Wesensten, N., et. al. (1998) Driving-Simulator Accident Rates Before, During, and After One Week of Restricted Nightly Sleep. *Sleep*, 21 (3 Suppl.), 235. (Abstract).

U.S. Department of Transportation, Federal Highway Administration. 49 CFR Part 395: Driver's Record of Duty Status; Automatic On-Board Recording Devices. Final rule and notice of termination of exemptions. September 30, 1988 (53 FR 38666).

U.S. Department of Transportation, Federal Highway Administration, Global Positioning Systems (GPS) Technology, Notice of interpretation; request for participation in pilot demonstration project. April 6, 1998 (65 FR 16697).

Wesensten, N., Thorne, D., Balkin, T., Redmond, D., Sing, H., et. al. (1998) Actigraphic Assessment of Commercial Drivers Over 20 Consecutive Days. *Sleep*, 21 (3 Suppl.), 237. (Abstract).

BIOGRAPHIES

Neill L. Thomas is the Chief, Vehicle and Operations Division, of the Federal Highway Administration Office of Motor Carriers and Highway Safety, Office of Motor Carrier Research and Standards. He has over 35 years of experience in the trucking industry in both the private and public sectors. Before joining the former Interstate Commerce Commission's Bureau of Motor Carrier Safety, he worked for regional and national motor carriers in positions ranging from driver to vice-president of operations.

Deborah M. Freund is a Senior Transportation Specialist in the Federal Highway Administration Office of Motor Carriers and Highway Safety, Office of Motor Carrier Research and Standards. She manages several major driver fatigue research studies in the OMC's human factors program, and has also done extensive regulatory development work concerning driver hours of service, motor carrier operations and safety fitness procedures, and CMV parts and accessories requirements. She holds bachelor's and master's degrees in civil engineering and transportation and urban systems from Washington University.

NOTE: This document is disseminated in the interest of information exchange. The United States Government assumes no liability for its contents or use thereof. The contents do not necessarily reflect the official views or policy of the Department of Transportation. This report does not constitute a standard, a specification, or a regulation.